and objects of activity as a whole in the conditions of uncertainty and competition with the use of regulatory documentation, modern methods of information search and processing, design automation tools based on modern information systems and best practices; development of methodological and normative documents, proposals and measures for implementation of the developed projects and programs, examination of technical documentation; conducting a patent search in order to ensure patent purity of new design decisions with determination of technical level indicators of the designed products of electromechanical and mechatronic systems; conducting analysis of competitive developments and implementation of feasibility study of design solutions, application of innovative technologies to solve engineering problems; development and implementation of energy and resource-saving measures in the design and operation of electromechanical and mechatronic complexes using the latest achievements; based on the analysis of static and dynamic loads, mode characteristics, to calculate and develop optimal equipment designs and operating modes of simple and complex electromechanical complexes using modern computer mathematical modeling methods.

There is a constant demand for specialists in electromechanical and mechatronic systems of energy-intensive industries thanks to the thorough preparation of masters, as well as the possibility of using the graduates of the department in almost all spheres of human activity, . This fact is confirmed by the full employment of the graduates of the department. The department of electromechanical equipment and energy-intensive industries is fully provided with long term contracts with enterprises for graduates.

References

1. EngineersMobilityForum: http://www.ieagreements.com/EMF

2. GraduateAttributesand Professional Competencies: http://www.ieagreements/.com/GradProfiles.cfm

3. Educational and professional program Electromechanical and mechatronic systems of energy-intensive industries of the second (master's) level of higher education. https://osvita.kpi.ua/node/103

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VARIANT ENERGY SAVING IN A COMPRESSOR INSTALLATION

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Annotation. *The effect of cooling on the lowering of specific energy consumption ofthe air compressionby the compressor installationwas investigated with the help of an exergy method of thermodynamic analysis.*

Keywords: *compressor installation, specific energy consumption, temperature, exergy method of thermodynamic analysis.*

Анотація. *З допомогою ексергетичного методу термодинамічного аналізу досліджено ефект впливу охолодження на зниження питомих енерговитрат стиснення повітря ступенем компресорної установки.*

Ключові слова: *компресорна установка, питомі енерговитрати, температура, ексергетичний метод темодинамічного аналізу.*

Introduction. The considerable energy intensity of compressor installations (KI) is explained by the physical phenomenon of simultaneous increase of the air temperature when it is compressed. At the same time, considerable work of the KI is caused by unwanted heating of air, and it is physically impossible to separate the processes of compression and heating of air. Therefore, it is urgent to search for unconventional ways to reduce energy consumption and the process of compressed air producing.

The seasons show a natural change in the specific energy consumption for the production of compressed air. The idea of this study is to force the inlet air temperature downstream of the compressor installations (even below ambient temperature) by the refrigerating cycle machines. So the air temperature reducing at the inlet to the stage of the KI by 3°C helps to reduce the specific energy consumption for air compression by 1%, that is explained by the increase in air density and facilitate the process of its compression.

Aim. The purpose of the work is theoretically to justify the feasibility and optimum depth of air cooling at the inlet to the KI stage, when the effect of cooling on the specific energy consumption of the compression is so important that it excessively can compensates for the additional energy costs for cold production. It is necessary to establish the dependences of the specific energy consumption on the compression of air and the production of cold as a function from the level of temperature to the cooled air at the inlet to the stage of KI. Total specific energy consumption is an extreme function that is subject to the minimum criterion optimization.

Materials and methods. The task for the establishing of the dependences of the specific energy consumption for the compression of the air ***L*** and the production of cold ***e*** on the air temperature is solved by the exergy method of thermodynamic analysis [1] with the determination of exergy efficiency of processes, or efficiency of the polytron process, $\eta_p$that accounts irreversible energy losses.

Results. Specific work for the air compression in the degree of KI is

$$L = \left(\frac{n \cdot R \cdot T_1}{(n-1) \cdot M} \right) \cdot \left(\frac{p_2}{p_1} \right)^{\frac{1}{\eta_p c_p}}, \qquad (1)$$

where$n$-is the polytropic index; R - is the universal gas constant; M -is the molecular weight of the gas; T_1 is the inlet temperature; p_1 p_2 - inlet and discharge pressures; c_p- specific heat of gas.

The ratio of the outlet and inlet pressures p_2 / p_1 is the degree of compression Ɛ, which can be expressed as a function of compression - the ratio of the outlet and inlet temperatures T_2 / T_1

$$\varepsilon = (p_2 / p_1)^{\frac{1}{\eta_p c_p}} = T_2 / T_1$$

Then the dependence of the specific work of compression remains as a function of the temperature conditions of the compression process

$$L = \frac{n \cdot R}{(n-1)M} \cdot T_1(T_2 / T_1 - 1) = \frac{nR}{(n-1)M} \cdot T_1(\varepsilon - 1) \qquad (2)$$

Thus, the specific work of compression of the degree of KI linearly depends on the air temperature at the inlet T_1, directed to the origin (to an unattainable absolute zero by a load of 0°K) and is reflected by the straight line L in Fig. 1.

The dependence of the specific energy for the production of cold $e$can be estimated by the exergy of the flow system of the refrigeration cycle machine [1]

$$e = (i - i_0) - T_0(S - S_0), \tag{3}$$

Where S, S_0, i, i_0 – instantaneous and initial values of entropy and enthalpy;
T_0 - initial temperature value (environment).

If we take the entropy zero as the coordinates of the thermodynamic state as initial conditions, then the dependence (3) after the corresponding transformations, as a function of the ratio of temperature and pressure will be written

$$e = c_p(T - T_0) - c_p T_0 (ln \frac{T}{T_0} - ln \frac{p}{p_0} / c_p), \tag{4}$$

where T i p - instantaneous values of temperature and pressure

Inthiscase, it is advisable to take into account the simplicity of only the temperature component of energyfrom (4)

$$e_T = c_p(T - T_0) - c_p T_0 \cdot ln \frac{T}{T_0}. \tag{5}$$

If we take the concept of relative temperature $t=(T-T_0)/T_0$ and use the Taylor transformation function, we obtain a finite dependence

$$e_T = c_p \cdot T_0 \cdot [t - ln(1 + t)] = c_p T_0 (t^2/2 - t^3/3 + t^4/4 - ...), \tag{6}$$

Analysis of dependence (6) shows that air cooling below the ambient temperature T_0 requires little specific energy consumption if the cooling air temperature T is slightly different from the absolute ambient temperature T_0. With significant differences between T and T_0, function (6) increases rapidly (see Fig. 1, curve e_T and their course from T_0 to the left at $T<T_0$). This fact gives a reason to hope that in a certain initial range of cooling temperatures $T - T_0$, the reduction of specific energy costs for compression of air L will be more advanced in relation to specific energy costs for the production of cold $e_T(- \Delta L > + e_T)$.

If this ratio is showed as

$$\omega = W_\Sigma / W_0, \tag{7}$$

where W_Σ - total specific energy consumption for compression (2) and air cooling (6)

W_0 is the specific energy consumption of the degree of air compression in a conventional KI (2), than the ratio (7) will be written taking into account (2) and (6):

$$\omega = T_1/T_0 + (T_2/T_1 - 1 - lnT_1/T_2)/(T_2/T_1 - 1), \tag{8}$$

Analysis of the graphical dependence (8) (Fig. 1, curve ω) shows that the air temperature by reducing at the inlet to the KI stage (to the left of the point T0, where $T<T_0$) reduces the total specific energy consumption for compression and

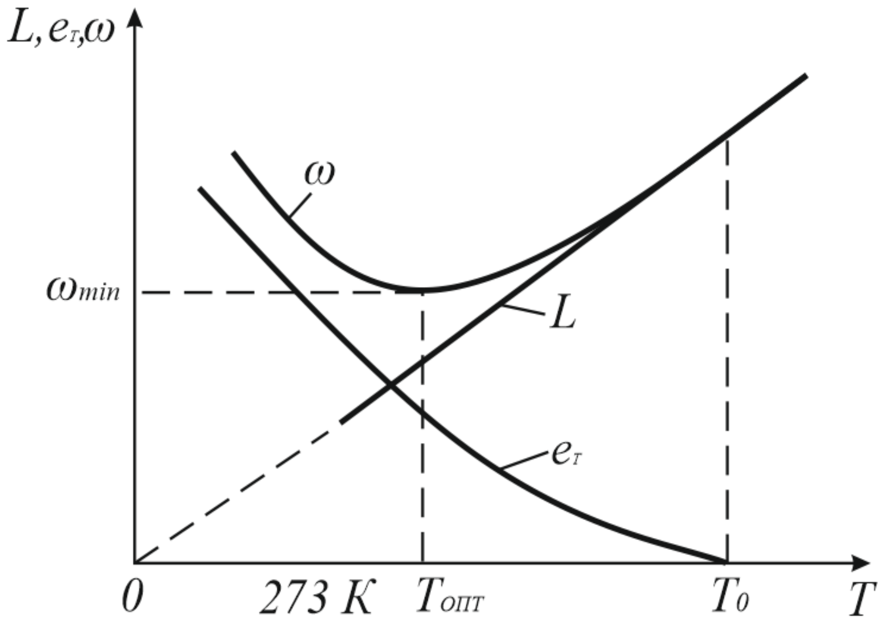

Figure 1 - Specific work of compression

air cooling and get their minimum value ω_{min}, and then their rash increase. The optimum value of the relative temperature cooling(T1 / T_0) that gives ω_{min} reaches

$$(T_1/T_0)opt = (T_2/T_1)^{-1}\ , \tag{9}$$

When we substitute the optimal ratio of temperatures (9) in the function (8) we determine the dependence of the minimum possible energy costs on the relative temperature T_2/T_1.

$$\omega_{min} = (T_2/T_1)^{-1}+[T_2/T_1-1-ln(T_2/T_1)^{-1}]/\ (T_2/T_1-1)\ . \tag{10}$$

It is important to note that if the ambient temperature (T_0>>273 ° K)is more positive, the effect of the cooling effect is greater . However, on the other hand, it should be noted that there is a restriction when T_0 is close to 273^0K and the optimum value of the cooling air temperature may be negative on the Celsius scale, which may cause the moisture that is separated from the air to be cooled by cooling. The formation of ice on the walls of the heat exchanger can lead to its complete clogging.

Conclusions. There is a temperature range of expedient influence on the reduction of the specific energy consumption of air compression in the degree of CO by the effect of its cooling at positive ambient temperatures (T_0>>273 ° K). There is a natural reduction of these energy consumption without the need for forced cooling to lower temperatures at the negative temperatures (T_0>>273 ° K)

References

1. Theory of heat engineering: workbook for foreign students of speciality «Applied mechanics», «Engineering mechanics» / Compilers: DeshkoV.I., Dubrovska V.V., ShklyarV.I., LenkinA.V., Stoudenets V.P. – K. : NTUU «KPI», 2011. – 118 p.: